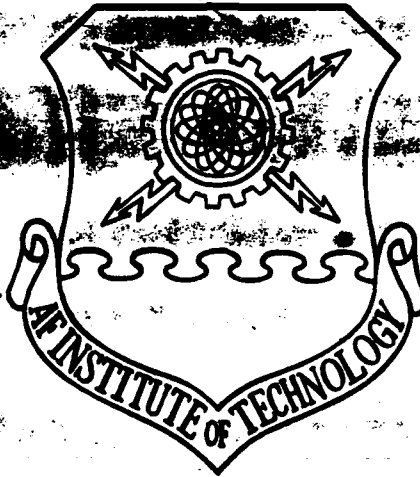


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AN INVESTIGATION OF INTEGRATED PRODUCT  
DEVELOPMENT TEAMS OF THE F-22 PROGRAM

THESIS

Gary F. Wagner, B.S.  
Captain, USAF

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AFIT/GSM/LAS/93S-19

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**AN INVESTIGATION OF INTEGRATED PRODUCT  
DEVELOPMENT TEAMS OF THE F-22 PROGRAM**

**THESIS**

**Presented to the Faculty of the School of Logistics  
and Acquisition Management of the Air Force  
Institute of Technology**

**Air University**

**In Partial Fulfillment of the  
Requirements for the Degree of  
Master of Science in Systems Management**

**Gary F. Wagner, B.S.  
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**September 1993**

**Approved for public release; distribution unlimited**

## Preface

The purpose of this study was to investigate how one leading Air Force Program was implementing Integrated Product Development. In this way other programs could increase the slopes of their learning curves by examining how another organization faced similar problems.

We would like to thank the interviewees who agreed to take part in the study. We would also like to thank our two advisors for their direction, Lt Col Michael Farr and Major Scott Graham. We would like to thank our wives Camille and Joy for their support and for being patient while we worked on this thesis. Finally, we would like to thank Hayley for all of her computer support on the thesis.

Gary F. Wagner

Randall L. White

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**Abstract**

This study investigated Integrated Product Development (IPD) at the F-22 System Program Office (SPO). A literature review revealed the six key IPD characteristics of organizational structure, communication, intense up-front planning, training, integrated management tools, and lessons learned. The research method was twenty-two one hour personal interviews of SPO subjects selected from the four IPD teams, the front office, and the functional support divisions. Key findings included an emphasis on up-front planning to establish an organizational and contractual structure which empowered workers to develop their products. Also, constant communication with all other functions and teams was stressed. Training was primarily done while transitioning to IPD but was beginning to be reemphasized. Each team member tailored his management toolbox to his own duties. Lessons learned included IPD is not a panacea for all acquisition problems and influences such as budgetary funding play major roles in program success. Both the Government and contractor must work to overcome the traditional adversarial relationship. The most difficult factor to overcome in implementing IPD is functional organizations concerned about career progression. The most important lesson learned was do not allow Integrated Product Teams to evolve into Independent Product Teams.

# **AN INVESTIGATION OF INTEGRATED PRODUCT DEVELOPMENT TEAMS OF THE F-22 PROGRAM**

## **I. Research Objective**

### **General Issue**

In 1976, the Office of Management and Budget (OMB) published OMB Circular A-109, which stated , "For a number of years, there has been deep concern over the effectiveness of the management of major system acquisitions." This circular established policies for all major acquisitions within the Executive Branch. Seventeen years later, deep concerns remain over how the Government conducts acquisitions, particularly within the Department of Defense (DoD). The cancellation of the Navy's A-12 program, the current controversy with the Air Force's C-17, and the forming of special presidential and congressional commissions on acquisition indicate problems still exist.

Air Force Material Command (AFMC), the Air Forces' weapons acquisition command, has recently been implementing a management philosophy called Integrated Product Development (IPD) in order to deal with these problems. The Air Force defines IPD as the following (1:24):

A team approach to systematically integrate and concurrently apply all necessary disciplines throughout the system life cycle to produce an effective and efficient product or process that satisfies customer needs.

IPD is a term the Air Force adopted from McDonnell Douglas for a concept called Concurrent Engineering (CE). Concurrent Engineering is defined in Institute of Defense Analysis (IDA) Report R-338 as the following (2:v):

A systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support. This approach is intended to cause the developers, from the outset, to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule, and user requirements.

The definitions of IPD and CE both reflect the idea of blending disciplines early in product development.

Concurrent Engineering developed as part of the "Lean Production" philosophy, a phrase coined in a Massachusetts Institute of Technology (MIT) study documented in *The Machine That Changed the World* (4). The Japanese automobile industry developed this philosophy with the goals of improving quality, productivity, production flexibility, and reducing product development time. This philosophy advocates collocated teams that use simultaneous engineering, design for manufacturing and assembly, flexible operations, and open sharing of information. Under IPD, these integrated teams are sometimes called IPTs, for Integrated Product Teams, or IPDTs, for Integrated Product Development Teams. Independent Product Teams and Independent Product Development Teams are used interchangeably in this thesis in order to cite different sources without modifying wording.

The IPTs are structured around major subsystems, such as aircraft avionics or engines. The IPTs are responsible for all aspects of their products, including technical, contractual, and financial issues. Other types of groups, such as functional

staffs, still exist within the IPD environment. The responsibilities of these other groups will be discussed in Chapter II.

In the 1980s, United States industries began to adopt CE design practices after witnessing the success of the Japanese. In 1991, the Advanced Tactical Fighter (ATF) Program adopted CE under the name of IPD as its approach to acquisition. In 1992, AFMC established a Working Group to develop and oversee the implementation of IPD within system program offices (SPOs) throughout the command (2:14).

### **Specific Problem**

Today's weapons systems are becoming more complex and expensive to acquire. Implementation of the IPD philosophy may enable program managers more effectively and efficiently to manage the cost, schedule, and performance risks associated with their programs. A case study which examines one program's implementation of IPD can help managers and their personnel learn how the philosophy has been implemented.

The research question for this case study is, "How are the F-22 System Program Office's (SPO) Integrated Product Teams currently implementing Integrated Product Development?" The research examines how IPD is impacting senior SPO management and lower level team personnel. The F-22 was chosen because it was the first Air Force program to implement IPD and it has been doing so for over two years. Therefore, the program was the best source of data in the Air Force for researching IPD.

## **Scope**

There were four potential areas of IPD implementation the researchers considered. The study could either be focused on how IPD was being implemented in mid-1993 or on how it was originally implemented in 1991. Additionally, the study could either be focused on the perspectives of senior management or lower management. Therefore, the IPD study could be divided into the following four areas:

1. 1991 senior management activities
2. 1991 middle and lower management activities
3. 1993 senior management IPD activities
4. 1993 middle and lower management IPD activities

This thesis examined areas three and four, which are the 1993 IPD activities of senior, middle, and lower management. Senior management included those people who led each of the SPO's functional branches, the front office, and the Avionics, Engine, Training, and Support IPTs. Everyone else in the SPO was considered part of middle or lower management.

This distinction between 1991 and 1993 was made for several reasons. The primary reason was to document the best IPD practices of the F-22 SPO. Because the F-22 was the first SPO to implement IPD at AFMC's Aeronautical Systems Center (ASC), it experienced many growing pains. When implementing new ideas, a SPO, like any other organization, makes mistakes and learns from them. A study of 1993

concentrated on successful activities rather than on practices that were no longer in use.

Another reason for the 1993-centered study was the difficulty the researchers would have had finding certain personnel to interview who were in the SPO in 1991. While some members of the SPO had worked there since 1991, many had moved on to other organizations. The scope of this thesis was limited to 1993 to ensure a thorough case study.

This research did not try to define IPD success within the F-22 since success is relevant to each organization's goals. Also, IPD is very new in the Air Force and deployment of systems acquired using IPD will not occur for several years. Readers of this case study should consider the characteristics of the F-22 Program when determining its relevance to their own programs. If the study is relevant, the reader may gain knowledge by studying how another major aircraft program's teams were implementing IPD.

### **Investigative Questions**

In order to understand how the F-22 implemented IPD, a set of investigative questions was developed that covered specific aspects of IPD. These investigative questions were:

1. How are the IPTs physically structured and how are the reporting chains-of-command configured?
2. How do the IPTs communicate internally within the teams and externally with other teams and customers?
3. How often and what type of planning do individuals and IPTs conduct?



4. How were the team members trained and how did they accomplish the cultural change to transition to IPD?
5. What types of integrated management tools did the teams use?
6. What major hurdles did the IPD teams encounter while implementing IPD and how were they overcome? What do the teams recommend other SPOs do to transition to IPD?

The above areas of IPD were developed after reviewing available literature on IPD and CE. Answers to these questions provide the necessary information to address the research question of "How are the F-22 Integrated Product teams currently implementing IPD?" As part of the literature review, briefing charts and draft implementation guides were examined to provide the researchers status on AFMC IPD implementation activities. The literature review in Chapter II provides a more detailed discussion of the tenets of IPD.

### Overview

The remainder of this thesis reviews available literature on IPD in Chapter II, describes the methodology for the research in Chapter III, details the results of the actual interviews in Chapter IV, and analyzes the findings and provides conclusions in Chapter V.

Chapter II is a literature review that contains detailed history of the development of CE and IPD in industry as well as the Air Force. It also describes the characteristics and elements of IPD. Finally, it provides some information on the F-22 Program itself. This chapter contains information ascertained from the literature review alone and does not contain any information from the interviews. Chapter III

addresses the research method, states how teams and personnel were considered for the interviews, and details how the actual interviewees were chosen. It also describes the formats and methods for the interviews. Finally, it describes how the data was analyzed. Chapter IV provides results from the interviews that answer the investigative questions. These answers are a summary of the important points brought out in each interview. Chapter V contains conclusions and recommendations for future research.

## **II. Literature Review**

### **Introduction**

This literature review begins with an introduction to IPD, followed by a short history of IPD's development. Next, the review details the elements and principles of IPD that Air Force members must understand in order to use IPD teams successfully. Third, short case studies of successful IPD employment are summarized and a brief background on the F-22 is given. Fourth, the review describes the various tools teams can use to employ IPD. The final section is a chapter summary.

This literature review investigated Integrated Product Development and how the Air Force can best use its cross-functional teams in its current acquisition programs. The Air Force defines Integrated Product Development (IPD) as the following:

A team approach to systematically integrate and concurrently apply all necessary disciplines throughout the system life cycle to produce an effective and efficient product or process that satisfies customer needs (1:24).

*The Results of the Aeronautical Systems Division Critical Process Team on Integrated Product Development* also describes IPD as the following:

IPD is an efficient process of bringing a product from user's needs to field operation. The basic principle is to iterate and integrate the design of a product and the design of its manufacturing, operation, support and training processes with specific focus on achieving low-cost development, production, operations and support within the shortest schedule while achieving robust quality of products and services (3:ii).

Department of Defense (DoD) programs can benefit from the use of IPD teams to meet the user's needs under more strict cost constraints. Most of this literature

review was limited to the AFIT Library and Wright State University Library using an online data network and off-the-shelf periodical review. Extensive data was also obtained from those AFMC program offices actively working to establish IPD teams. Most of the AFMC data is in the form of briefing slides presented during senior level decision making meetings. These slides were obtained from Colonel Tom Bucher, the Co-chairman of the AFMC IPD Working Group tasked with implementing IPD for the Air Force. Thus, the slides contained some of the most recent conflicts, issues, and information on the Air Force's development of IPD.

### **History**

Concurrent Engineering (CE), the original name of IPD, evolved in the 1970s (1:14). It is defined in the Institute of Defense Analysis (IDA) Report R-338 as the following:

A systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support. This approach is intended to cause the developers, from the outset, to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule, and user requirements (2:v).

Concurrent Engineering developed out of the Lean Production philosophy detailed in *The Machine that Changed the World: The Story of Lean Production*. Lean production emphasizes teamwork, communication, efficient use of resources, elimination of waste, and continuous improvement (4).

The Japanese automobile industry developed this philosophy with the goals of improving quality, productivity, production flexibility, and reducing product development time. This philosophy removes all non-value added activities to

minimize waste of equipment, space, and people. This is achieved through collocated teams that use simultaneous engineering, design for manufacturing and assembly, flexible operations, and open sharing of information. The Lean Philosophy emphasizes building quality in from the beginning and then continually improving throughout the process (5:7-8).

In the 1980s, the United States industries began to adopt CE design practices after witnessing the success of the Japanese. In 1988, the IDA report on concurrent engineering was published. In 1990, the Advanced Tactical Fighter Program adopted CE under the name IPD as its approach to acquisition. During 1990 Lieutenant General Loh, then Aeronautical Systems Division Commander, established an IPD critical process team to create a culture to integrate the IPD ideas into the acquisition process (3:1). During that same year, Air Force Systems Command's (AFSC's) Horizon Conference assigned an action item to develop IPD. In response, AFSC formed a senior management level IPD Steering Committee in 1991 to provide guidance to the field. During this period, various programs had been implementing decentralized IPD. In 1992, the new Air Force Materiel Command (AFMC) established a Working Group to develop and oversee an IPD implementation transition plan and to resolve IPD issues (2:14).

### **IPD Background**

The IPD Critical Process Team Report contains a good background on IPD. The Executive Summary of the report states:

The IPD approach requires the simultaneous and integrated development and qualification of all the elements of a total system as contrasted to a sequential development process. It focuses on establishing Integrated Product Teams at the "doing level" to ensure that all functional and special interest groups are "integral contributors" rather than "monitors" in the process. For IPD to be successful, the development process must change what people do, and when they do it, so that they actively participate by creating products that incrementally define the total system. IPD increases the focus on, and "ownership" of, the products and processes, improves horizontal communications, establishes clear lines of responsibility, delegates authority, establishes clear interfaces with industry, and changes the acquisition process expectations so that the activities and success criteria are based on the total product including its manufacturing, support, and training (3:ii).

### **IPD Characteristics**

IPD characteristics incorporate a lot of common sense. One of the IPD

Working Group's presentations states the key IPD characteristics are the following:

- 1) a product minded orientation
- 2) the use of cross-functional teams
- 3) intense up-front planning
- 4) the use of integrated management systems (1).

This thesis focuses on the use of cross-functional teams (IPD teams) but describes all four of the above characteristics. IPD and concurrent engineering are interchangeable phrases. Therefore, much of the literature reviewed was also about concurrent engineering.

The previous concurrent engineering definition emphasized product orientation, the first characteristic (2:v). Dr. Jerome Lake, a professor of systems engineering at the Defense Systems Management College (DSMC), stated, "Current systems engineering practices result in fragmented, sequential design of the . . . functions of a

system"(6:19). This occurs in programs where the product is not the focus of attention.

Brigadier General Fain, the F-22 Program Director during source selection, suggested the Air Force was also emphasizing product orientation. An introductory chart from one of Fain's program briefings is entitled "Product - Oriented Versus Process - Oriented" (7:6). It states that combining a poor product with an excellent process still results in an expensive failure.

A product orientation requires all possible functional areas to focus their attention on one product, not on their own functional concerns. This leads to the team approach to product acquisition.

The second characteristic of IPD is the use of teams. Lake's article, sponsored by the Under Secretary of Defense for Acquisition, discusses a workshop held in November of 1990 and specifically supports the use of a team approach. Lake states the following:

Without multidisciplinary design teams working on the various aspects of the iterative systems engineering process, the maladies of systems engineering as practiced will be repeated. . . (6:20).

Lake is referring to the problems experienced with systems engineering, which is the current approach to product development. He believes that systems engineering has not accomplished in practice the things it promised in theory.

The team concept is also emphasized by industry. "Multi-Discipline Teams: A Fundamental Element of the Program Management Process," reviews several successful programs at The Boeing Company that employed these teams. These

programs include the F-22 Advanced Tactical Fighter, RAH-66 Comanche Helicopter and 767 Airborne Warning and Control System (8:13).

Besides emphasizing teams, Air Force documentation states it is important to "match government and contractor IPT's"(1:35). An IPT is an Integrated Product Team, the organization that does the necessary work to implement the IPD philosophy (1:17). Also, the IPD Critical Process Team report states the following:

A key feature of successful implementation of integrated product development is the establishment of collocated, multifunctional, empowered, integrated product development teams (IPDTs) (3:27).

The report also states that early involvement of all disciplines working as a team to integrate requirements and schedules reduces rework in design, manufacturing planning, tooling and product support planning. Most important is the teams provide equal emphasis on both product and process development. Key team success issues are organizational structure, human resource development and cultural change (3:27).

The report also envisions four types of teams: management teams, integrated product teams, functional teams, and special teams. The management team consists of the program manager and the functional directors and is responsible for overall policy, guidance and review of the other teams (3:28). The IPTs should be structured around the major subsystems of the specification tree and should be tailored for each program (3:29). Functional teams are established to develop cohesive strategies to guide and ensure consistent practices across the IPTs. They should ensure proper allocation of a set of appropriate level performance oriented requirements. Other special SPO teams may be established as needs dictate (3:30). Once teams are



formed, all members should be trained on IPD principles and team techniques. The IPD process requires extensive communication within the team and with outside customers (3:32).

The third characteristic is increased up-front planning. Increased up-front planning is linked to Air Force IPD implementation. Although industry agrees planning is important, it is not usually listed as an industry IPD characteristic as it is in Air Force briefings. The September 1992 draft of the "IPD Implementation Guide" emphasizes increased planning. Colonel Bucher's briefing to the initial AFMC IPD Working Group also categorizes planning as a characteristic. Integrated Product Team planning is formalized when milestones necessary to track a product are established. The Integrated Master Plan (IMP) is the culmination of this process (1:33). A specific schedule for these events, called the Integrated Master Schedule (IMS), flows out of the IMP (1:38).

The fourth characteristic is the use of integrated management systems. One Air Force example is the use of a single numbering system to facilitate document tracking and managing (9). *Production Engineering* states the following in the article "Integrated Manufacturing":

It's the team's job to integrate planning, marketing, processing, flow of information and material, direct and indirect labor, quality assurance and capital investment into an integrated manufacturing strategy (10:IM2).

C.B. Tatum, Associate Professor of Civil Engineering at Stanford University, discusses the benefits of a management system that integrates the design and construction engineers of a facility planning project. He states the construction

engineers "select construction methods and sequences in order to request designs which support this plan" (11:97). The design engineers then have a better idea of what they need to design.

The four IPD characteristics described above were the basis for the investigative questions listed in Chapter 1. They provided the most succinct description of IPD available. However, immediately preceding the first interviews within the F-22, the AFMC Commander endorsed a White Paper that described eight tenets for IPD (18:3-5). These tenets are:

1. Integration Throughout the Life Cycle
2. Product Focus
3. Seamless Management Tools
4. Up-front Planning
5. Cultural Change
6. Right People, Right Place, Right Time
7. Empowerment
8. Teamwork and Communication

Items two, three, four, and eight of this list are similar to the four characteristics previously described in this chapter. The elements of "Cross-Functional Teams" and "Right People, Right Place, Right Time" were combined to form investigative question one, "How are the IPTs physically structured and how are the reporting chains-of-command configured?"

The communication aspect of the AFMC Commander's eighth tenet was the basis for question two, "How do the IPTs communicate internally within teams and externally with other teams and customers?"

The up-front planning element from both lists became question three, "How often and what type of planning do individuals and IPTs conduct?"

Investigative question four was a reflection of the "cultural change" tenet of the Commander's White Paper. Worker training in a variety of areas was a common literature theme relating to commercial businesses and therefore was of interest to the researchers.

Integrated management systems and tools was a tenet on both lists of IPD elements and therefore became question five, "What types of integrated management tools did the teams use?"

The researchers wanted to provide other SPOs any lessons learned or other advice the F-22 subjects might be able to offer to help others implement IPD. Therefore, question six was, "What major hurdles did the IPD teams encounter while implementing IPD and how were they overcome? What do the teams recommend other SPOs do to transition to IPD?"

Another very important IPD element was a product focus by the teams that was emphasized on both lists. The researchers felt a product focus should be prevalent in all the other elements of IPD. Therefore, specific questions about a product focus were added to some sections of the interview questionnaires.

### **IPD Case Studies**

Many programs have successfully employed the above IPD concepts. Air Force programs can look at them for guidance in developing their own IPD teams. The first example of an IPD program is the Boeing 777 Transport. The team approach is the cornerstone of this program. It aims at doing things right the first time to avoid the costly changes that occur downstream when a part cannot be manufactured as designed. This also causes reduced flow time. Two hundred design/build teams include representatives from nearly every Boeing function involved in producing the transport, including customer and supplier representatives. Boeing organized these teams around parts of the aircraft, rather than functions. A manufacturing expert involved from the beginning makes it less likely for designers to release a part that is difficult to produce and must be redesigned. Boeing is also striving for a one hundred percent digital definition of the 777, using two thousand computer terminals with three dimensional design to reduce hand drawings, mockups, and models (8:18-19).

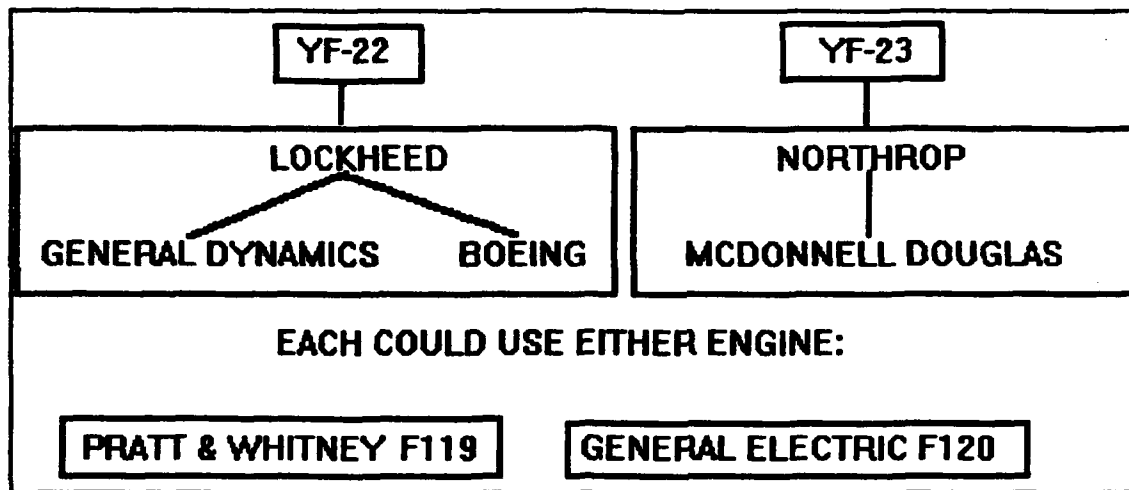
The Chrysler Viper Automotive Program has the entire design and manufacturing team working together in a large room. The team is within walking distance of the area where they assemble some of the cars. The team stresses keeping the program simple and integrating multiple disciplines. It also uses computers to do scheduling and computer aided design (CAD). Designers released fifty percent of the tooling from CAD without using paper drawings. This team consists of a horizontal organization with three levels, and it uses a no-walls concept to enhance

communication and simultaneous engineering. The no-walls concept refers to Chrysler removing physical and organizational barriers between team members that could hamper communication. The Viper team had several noteworthy accomplishments. The car reached limited production in a record time of 3 years at a budget much lower than those of previous programs. It cost one hundred million dollars, which is five percent of what other companies lavish on a new-car design. Finally, the Viper team developed several new technology designs such as an aluminum V-10 engine with 488 cubic inches displacement (12:12-13).

### **F-22 Background**

Next, a short background is given on the F-22 program itself. This information was acquired during the literature review process and it provided an initial exposure to familiarize the researchers with the F-22 organization.

Competition and prototyping were two of the priorities of the Advanced Tactical Fighter (ATF) acquisition. Contractor teams competed for two contract awards; one for the main airframe and one for the engine. Figure 2-1 depicts the contractor teams that competed for award. Lockheed and Northrop led contractor teams that conducted a fifty-four month long demonstration and validation program involving the design, construction and flight testing of prototype aircraft. Pratt & Whitney's F119 engine and General Electric's F120 engine competed. The program conducted a competition between both airframe and engine teams before the selection of the contract winners in April of 1991. Air Force Secretary Donald B. Rice emphasized that the flight test program was not a fly-off in which the Air Force



**Figure 2-1. ATF Competitors**

directly compared performances of the competing aircraft. Instead, it evaluated how much each aircraft/engine combination assured the Air Force that the companies would do what they proposed. The companies were free to demonstrate whatever capabilities they considered necessary to back up their development proposals (13:21).

The contract statement of work was general in nature in the spirit of telling the contractor what to do and not how to accomplish it. The specifications only listed functional, not design-to requirements. The objective was to allow the contractors freedom to explore solutions and to reduce risk in a competitive environment under government guidance, not direction. An event driven Integrated Master Plan combined with an Integrated Master Schedule helped drive the planning and funding environment. The plan is contractual and describes how to run the development program on an event based schedule to develop the airframe, avionics, support and training systems (9:27). The use of contractor generated documents, such as the IMP and IMS, was a step back from using rigid military specifications.

The F-22 development concept included iterative design of the fighter's structure with the goal of eliminating design changes once fabrication begins. This will minimize schedule slips and cost increases. The F-22 is developing according to the IMP, which sets out what has to be done, and the IMS, which states when it has to be done. Integrated product teams that bring together all the required disciplines handle the work packages. Each of these teams has a schedule and a budget (7:33-34). The teams include design, system, reliability, and maintainability engineers and also manufacturing representatives, all working together to increase quality (14:26). IPD is resulting in an airplane built with producibility in mind.

The Air Force awarded Lockheed and Pratt & Whitney two Engineering and Manufacturing Development (EMD) contracts that sum to roughly thirteen billion dollars. Figure 2-2 provides a broad schedule of the Engineering and Manufacturing

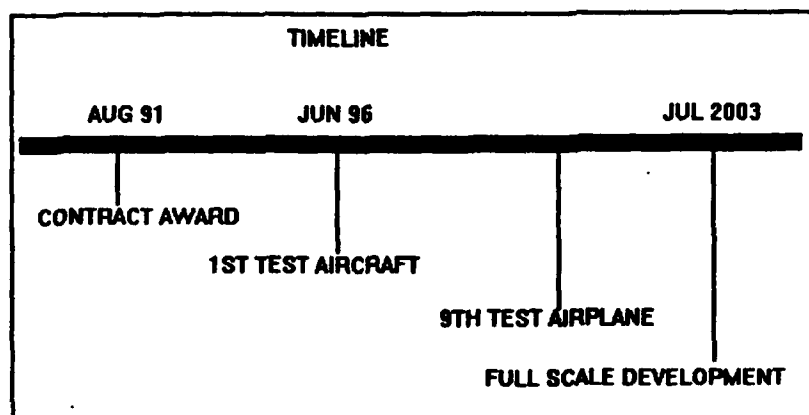


Figure 2-2. EMD Schedule

Development (EMD)

phase of the F-22

program. The contracts

will complete detailed design specifications and

prepare engineering drawings. They also

will procure nine EMD

aircraft for flight testing and two aircraft for stress testing. Finally, they will procure twenty-seven engines to support flight testing, which will begin in 1996. The cost-

plus-award-fee contract allows reimbursement of contractor costs plus a base fee of four percent. The Government evaluates contractor performance semiannually to award up to an additional nine percent (15:4). The contract is fair to both sides, providing a small base fee for development and a large award fee for meeting goals and timetables (14:28).

The decision to proceed with full scale development occurs in 2003. The total projected buy is 648 fighters with a final price tag of 82.830 billion dollars by the time the Air Force pays for the final order in 2014. Excluding projected inflation, the cost is 56.905 billion dollars; 12.678 billion dollars for development and 44.227 billion dollars for production (16:34). These figures exclude the demonstration-validation phase which costs 3.804 billion dollars without inflation and 3.780 billion dollars with inflation.

### **IPD Tools**

This section summarizes some of the IPD tools a program manager may use. In one F-22 briefing, Brigadier General Fain stated that the IPD tools themselves did not change from the tools used under systems engineering. The difference is they are used more effectively (7:9).

According to the Space and Missile Center IPD guide, these tools include contractual elements, such as the Work Breakdown Structure (WBS), the Statement of Work (SOW), the Integrated Master Plan (IMP), and the Integrated Master Schedule (IMS) (9:36). Another common tool is the specification. "It is envisioned that the formulation of IPDTs within major SPOs would be formed around the specification



tree" (3:24). The highest level specification is the A specification. It is the overall system specification. The other two levels are the development specification, or B specification, and the product specification, or C specification. The IPD guide states that management should occur at the A specification level, with Government taking control of subsequent specifications as late in the program as possible (11:52-53). Since this is only one guide, other views on the timing of this control could be incorporated. Further discussion of specification use can be found in the IDA report.

Another important tool is the use of Technical Performance Measures (TPMs). Technical Performance Measures regularly demonstrate through test or predict through achievement selected technical objectives of systems, subsystems, or components. Technical Performance Measures can be used to account for the differences between results and planned objectives. This permits managers to take corrective action for indicated problems. Technical Performance Measures involve prediction, tracking, reporting, and variance analysis of technical parameters. Specific TPMS should be included in the achievement criteria identified in the Integrated Management Plan. Examples include system weight, maximum payload, and engine thrust (11:57-58).

### **Summary**

This literature review provided background material for this study on how the Air Force is using Integrated Product Development teams on the F-22 Program. The review began with an introduction and then described the evolution of IPD over the

last thirty years. Next, the review detailed the elements and principles of IPD that the Air Force is examining in order to use IPD teams successfully. Two case studies of successful IPD employment by Boeing and Chrysler were summarized and a background of the F-22 was described. Finally, the review described the various tools teams can use to employ IPD.

The next chapter outlines the methodology used in this research effort. An in-depth case study provided the most appropriate methodology to obtain detailed information on how the F-22 program was using IPD teams.

### **III. Methodology**

#### **Introduction**

A case study was used to explore the use of integrated product teams within the F-22. This chapter justifies the use of a case study and explains the tasks performed to complete it. These tasks included research design, sample plan development, research instrument development, actual data collection, and data analysis.

#### **Research Design**

This research examines how Integrated Product Teams (IPTs) can be used in one Air Force program. A case study is a valuable tool for providing in-depth information about a specific organization or problem. It enables researchers to analyze a limited number of events or conditions and their interrelations. An emphasis on detail can provide valuable insight for problem solving, evaluation, and strategy. A case study also allows data to be secured from multiple sources, which permits evidence verification and minimizes missing data (17:142-143).

Case studies can be valuable teaching tools and vehicles for others encountering similar problems. Studies which closely resemble actual situations others encounter are usually more valuable to them. For this reason, a case study of the F-22 IPTs is important. Information about non-military developments, such as the Saturn automobile, is useful but may not directly address the specific environment of

a military organization. An F-22 case study may help more military personnel learn about IPD than a study of non-military programs.

### **Sampling Plan**

The population for this study consisted of all current members of the F-22 SPO. Throughout this thesis, the words he and his are used interchangeably for both males and females. It was not feasible to interview all SPO personnel because of their diverse schedules and because of time constraints, so a representative sample had to be selected. In order to make the case study reflective of the entire F-22 SPO, the researchers chose to sample from throughout the organization.

Proper sampling still provides quality information. Emory references a Deming argument "that the quality of a study is often better with sampling than with a census."(17:242) Emory also cites research that "More than 90 percent of the total survey error in one study was from nonsampling sources, and only 10 percent or less from random sampling error."(17:242)

The sample size was dictated by the time frame of this study. The interviews were conducted in May to early July, 1993. Twenty-two interviews were conducted. Twenty of the subjects were interviewed independently and two, the program director and deputy program director, were interviewed jointly. Purposive sampling was mixed with judgmental reasoning and quotas. This nonprobabilistic type of sampling was justified by Emory because there was no need to analyze statistically any specific parameters (17:273).

The sampling was purposive because each of the interviewees was chosen for a specific reason such as SPO position or involvement level in IPD implementation planning. The researchers used their judgement to determine which individuals in which particular positions needed to be interviewed.

The above rationale was used to interview major subsystem IPT leaders, functional chiefs, and other selected IPT members. The primary constraints to interviewing necessary personnel from the IPTs and functional directorates were time and personnel availability.

### **Research Instrument Development**

The researchers used personal interviews because they provided the greatest detail while enabling the researchers to best control the data gathering process (17:320). Interview subjects were accessible since the F-22 is located at Wright-Patterson Air Force Base (AFB) in Ohio. Personal interviews also allowed the researchers to witness facial expressions and other body language. Telephone interviews or questionnaires would not have allowed the same amount of open-ended questioning and free flow of information.

The primary interview aid was an informal questionnaire. The interviews included both structured and unstructured questions, depending on the level of information desired on a topic. The initial questions for each topic were simple, focused, and closed. This established the topic before pursuing more detailed information and also awakened the subject's interest (17:370). More complex questions followed, which led to open-ended questions soliciting personal opinions on

the information just covered. This process of moving from structured to unstructured questions and from simple to complex is known as following a funnel approach (17:371).

Detailed interview questions were developed to address each related investigative question as a whole before addressing another investigative question. Shifting of focus would have decreased the respondent's motivation and hampered understanding of the questions (17:372).

Question wording was another key area to consider. A SPO often has its own technical language and jargon. Even highly educated people from outside a SPO will misunderstand words and phrases specific to that SPO. This can contribute to misunderstanding during the interviews. (17:362) The researchers tried to develop a solid background on the SPO and its language through the literature review process. They also interviewed former F-22 members who were current AFIT students. Developing a knowledge of the F-22 language helped the researchers develop questions that made sense to F-22 members. In addition, it helped the researchers interpret answers to the questions.

The questions were not disguised in any manner. The researchers requested only information the respondents would be able to provide. Respondents were willing to answer the questions because prior approval was obtained from the SPO Director and because no personal information was requested.

Researchers pretested the interview questions and process on AFIT students who were previous members of the F-22 SPO. The students critiqued the questions

and interview process to offer improvements for interviewing the F-22 members. In addition, two thesis advisors provided valuable critiques of the interview questionnaire.

### **Pre-Interview Activities**

An informal questionnaire was provided to each interviewee several days before conducting the interview. This questionnaire is included in Appendix A. This step served two purposes. First, it allowed the subject to prepare for the interview and gather any data necessary for the interview. Second, it helped establish rapport with the subjects, which motivated the interviewees and contributed to their responsiveness (17:360).

### **Data Collection**

The subjects were interviewed one at a time by both of the researchers. The only exception was the joint interview of the Program Director and Deputy Program Director. One researcher was responsible for guiding the interview process to ensure each major topic and related questions were discussed. The second researcher took detailed notes during the interview. The interviews were also tape recorded with approval of the subjects. Three of the interviews were not recorded because of recorder or battery problems. Each interview took approximately one hour.

The researchers interviewed one subject at a time to obtain a wide exposure, as well as individual opinions, of IPD implementation. Focus group interviews were

not employed because they may have stifled individual responses and instead provided group ideas.

After each interview, the researchers wrote a transcript based upon the written notes taken during the interview. This transcript was then reviewed while listening to its cassette tape and necessary changes were made.

### **Analysis**

The specific interview questions were designed to answer the six investigative questions. The analysis in Chapter IV contains a summary of the interview responses organized by investigative question. The researchers reviewed the transcripts one section at a time and summarized the important responses and findings. These findings answer each of the investigative questions and provide insight into IPT activities.

Chapter V examines these findings and answers the general research question. Chapter V also describes research weaknesses and potential ideas for further study.



## **IV. Results**

### **Introduction**

This chapter presents the results of the interview questions. Each of the interview questions related to one of the following six areas:

1. Organizational Structure
2. Communication
3. Intense Up-Front Planning
4. Training
5. Integrated Management Tools
6. Lessons Learned

The interview responses were summarized and grouped according to these areas. The related investigative question is stated at the beginning of each section. The next section provides background on the interviewees.

### **Interviewee Background**

The interviewee background section had two purposes. First, it explained the subject's position and what his day to day duties entailed. This helped the researchers understand other responses during the remainder of the interview. Second, the background section provides simple questions to ease the subject into the interview. The subjects were guaranteed anonymity so no detailed information will be provided.

The following summary background information provides the reader general knowledge on the interview subjects. This section does not relate to any specific

investigative question and only provides descriptive information. The subjects joined the SPO as early as the summer of 1983 to as late as August 1992. Twenty-two members of the SPO were interviewed, including the Program Director, a Deputy Program Director, and the Technical Director. Half of the subjects were military and half were civilian. Table 4-1 depicts the subject representation from throughout the SPO.

**Table 4-1. SPO Representation**

<u><b>IPT Teams</b></u>	<u><b>Functional Support</b></u>	<u><b>Front Office</b></u>
Air Vehicle - 7	Projects Div - 3	3 Members
Support System - 2	Engineering Div - 2	
Engine - 2	Contracting Div - 1	
Training - 0	Financial Mgmt Div - 1	
	Test Div - 1	

The subjects included IPT leaders, sub-IPT leaders and members, functional support personnel and front office personnel. Each member of the four primary IPTs was usually dedicated to one sub-IPT but also supported the other sub-IPTs. Some also supported the three other main IPTs. All the civilian subjects working on IPTs supported the same product throughout their assignments in the F-22 SPO. This was also true for most military personnel except for project managers who spent a year in the Projects Division before becoming full-time members of the four major IPTs.

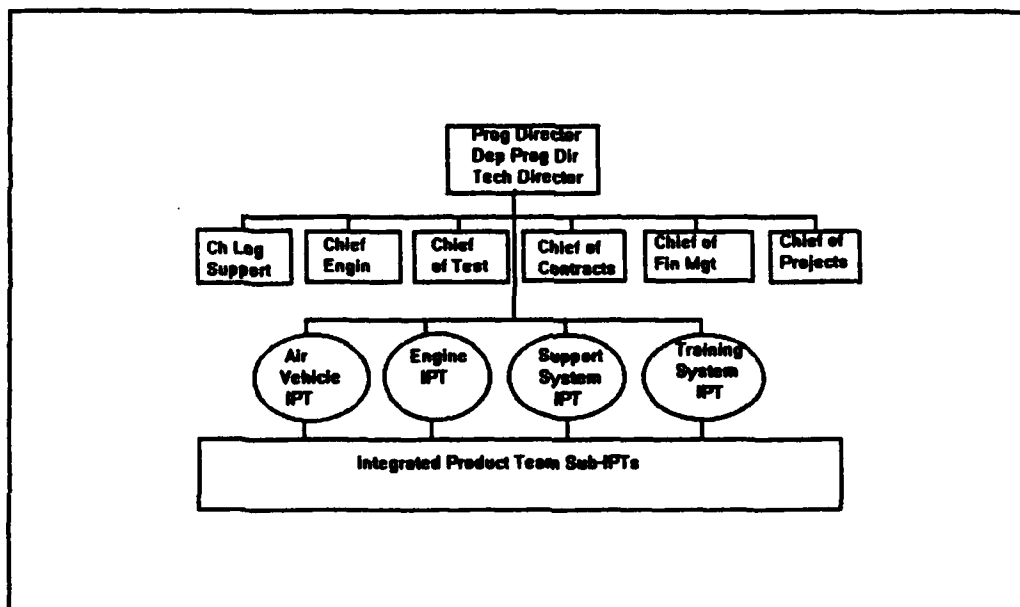
IPT members stated their missions were developing and deploying their particular products. Most of them described how their products fit into the total F-22 weapon system. Each of the functional personnel divided his duties between

supporting one of the four IPTs and supporting all four IPTs at the weapon system level. The next section provides a summary of interviewee responses related to the SPO's IPD organizational structure and chains-of-command.

### Organizational Structure

How are the IPTs physically structured and how are the reporting chains-of-command configured?

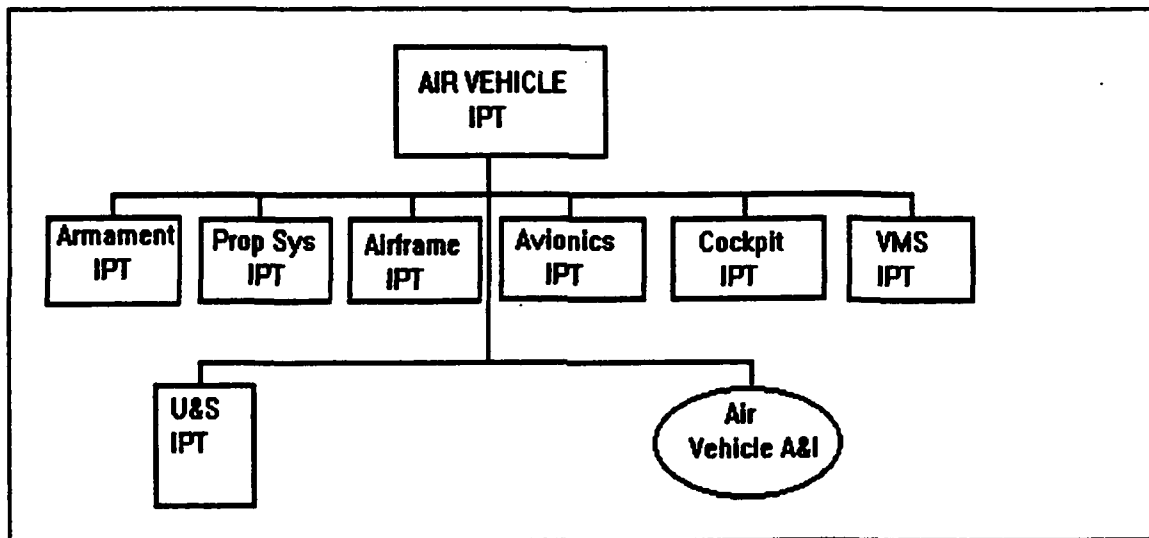
The four primary IPTs were the Air Vehicle IPT, the Engine IPT, the Training IPT, and the Support Equipment IPT. Figure 4-1 depicts an organizational chart of the F-22 IPT structure.



**Figure 4-1. IPT Organizational Chart**

Each IPT had two team leaders; usually one was an engineer and one was a program manager. Subjects did not perceive any conflicts arising from two team leaders giving different directives. Each IPT was divided into many sub-IPTs. For example, the Air Vehicle IPT included the Armaments, Propulsion System, Airframe,

Avionics, Cockpit, Utilities and Subsystems, and Vehicle Management System sub-IPTs. There was also an Air Vehicle Analysis and Integration team whose role will be discussed later. Figure 4-2 depicts the Air Vehicle IPT.



**Figure 4-2. Air Vehicle IPT Organization**

Each sub-IPT had a core of engineering (EN), program management (PM), and logistics (AL) people but also received part time support from contracts (YFK), program control (YFP), and test (YFT) organizations. Engineering and logistics personnel were distributed throughout the teams and included design, manufacturing, and reliability engineers as well as logistics personnel.

The functional contracting and finance personnel were usually assigned to one of the four IPTs and supported all that team's sub-IPTs. Therefore, functional personnel were often members of anywhere from two to six sub-IPTs. There was a separate test team responsible for developing vehicle test planning. This team was not considered an IPT because it did not provide a hardware product. Its members

supported all of the IPTs. There was also a projects division that accomplished various jobs to support the IPTs.

There were also Sacramento and San Antonio Air Logistics Center representatives and Headquarters Air Combat Command (ACC) representatives. In addition, one officer and two enlisted Air Combat Command local representatives were permanently assigned to the SPO. Interview subjects indicated the representatives, particularly the enlisted personnel, had strong aircraft maintenance and support backgrounds and therefore provided user inputs for requirement issues. More pilot-oriented performance requirements were dealt with through contacts at HQ ACC who acted as focal points for the individual teams.

Analysis and Integration (A&I) teams were considered absolutely critical by the Program Director. These teams ensured the product teams do not work independently. The Weapons Systems IPT was also formed to ensure cross-team integration between the IPTs. This team consisted of the functional leaders and the four IPT leaders and met once a week. The Deputy Program Director normally chaired this team although the Program Director often attended the meetings.

About half of the IPT subjects said they supported another primary IPT's sub-IPTs. However, none considered themselves actual members of these teams. This excluded the IPT leaders who were also members of the Weapon System IPT that handled major integration issues between the IPTs.

There were no contractor representatives physically located in the SPO, but several subjects indicated they often see local contractor representatives conducting

business in the buildings. Also, computer support and security service contractors permanently resided in one building.

The personnel of the four IPTs usually resided together in one building. However, because of construction work, the Air Vehicle IPT was temporarily divided between two buildings because the avionics group resided in temporary offices. The only team members who did not normally reside with the IPTs and sub-IPTs were the contracting and finance personnel. The contracting personnel were temporarily moved to the basement of the building due to the construction. The finance personnel were located in another building. However, the contracting and finance personnel were normally separated from the IPTs for three reasons. First, there was not enough manpower to allow dedication of a functional representative to each IPT sub-team. Second, most of the functional members spent half of their time on weapon system issues that concerned more than one team. They needed to communicate with other functional workers as well as their IPT teammates. Third, they used common data bases and references such as the Federal Acquisition Regulations (FAR) that were too cumbersome to place in each IPT's area. A functional person would have had electronic access to his functional data base from most locations in the SPO. However, the functional management personnel had the expertise to use it. This was considered more crucial to the contractual and financial functions where the data bases had legal ramifications as opposed to engineering tools that usually did not. Another advantage of being located with other functional personnel was they could obtain training that would not be available if they were located with IPTs. One disadvantage

of being separated from the IPTs was support personnel were sometimes left out of the communication loop or let in after an issue was already being worked.

Another commonly stated advantage of collocation was enhanced communication. One air vehicle sub-IPT leader mentioned the difficulty of managing integration issues due to the physical division of his team caused by the building refurbishment. He compared this to the ease with which the team communicated when it had been located together. A few of the sub-IPT leaders indicated it would be beneficial to have their contracting and financial support collocated with them but they did not consider it an absolute necessity.

Contracting, projects, and finance personnel reported through chains of command within their functional divisions. The teams they supported contributed to their performance evaluations but their functional *directories* were the final authority within the SPO. The Aeronautical Systems Center (ASC) home offices of the functional civilians acted as their performance appraisal approval authorities. Home offices were defined as organizations that provided matrix support personnel for each functional discipline to the ASC SPOs and thus were responsible for the career progression of their personnel.

Sub-IPT military personnel reported to their sub-IPT leaders, IPT leaders, and finally the front office. Officer Performance Reports (OPRs) were reviewed by three higher ranking officers not in the officer's chain-of-command in order to ensure reports were written fairly across the SPO. Team leaders wrote civilian personnel

evaluations but final approval remained with the ASC home offices. This included all engineers, program managers, and logistics personnel.

Control over civilian evaluations was a controversial topic. Many subjects indicated the SPO was trying to gain control of its civilian performance evaluations. This effort included SPO representation on an Air Force Material Command (AFMC) Process Action Team discussing the issue. The SPO's senior civilian leadership was divided on this issue. Several leaders supported SPO control of the evaluations. However, another senior civilian supported the existing SPO process since changing it required changing the entire Air Force and DoD civilian personnel system.

This evaluation process began with this civilian lobbying the ASC home offices. He stressed the F-22 was a leading DoD procurement employing a higher proportion of the top civilians on the base. This often resulted in the F-22 SPO receiving a higher percentage of "superior" or "excellent" ratings for its members than other units. This same civilian believed if the civilians reported via a team-oriented chain of command the SPO would obtain a lower proportion of high civilian ratings. Team and sub-team leaders would not have the same success as the SPO's senior civilian leader in lobbying the home offices.

Most military subjects did not feel accountable to more than one chain since their team day-to-day chains running through their IPT leaders were also their military reporting chains. For civilians, the team chain-of-command was a working chain to use for issues involving their products. Most civilians did not see any problems with having both team and functional chains, even when they were aware of



the different paths of accountability. About one fourth of civilians did express a problem with their current situations.

One common problem of the AL logistics personnel was they did not know who in the SPO was protecting their interests within the ASC home office. Therefore, they felt more comfortable with their team chains-of-command and preferred that ASC/AL not have any approval over their evaluations. However, the contracting and finance subjects were very definite about wanting to keep their functional chains of command. They felt the IPT team leaders did not see many of their activities. They preferred the team leaders only to provide inputs to their performance evaluations.

Almost all the subjects felt comfortable with the SPO structure as it existed. However, one subject thought the IPT structure was confusing because of the proliferation of teams, sub-teams, and functional organizations. This subject was also disappointed that the integrative nature of the program detracted from the time engineers could devote to engineering tasks since they had to become familiar with management issues such as cost and schedule variances. Another subject was frustrated that the civilian personnel system made it difficult for engineers to receive credit for the management and supervisory duties they did.

A majority thought team member skill levels were appropriate. However, one of the functional subjects indicated many of the newer IPT members were unfamiliar with the capabilities and responsibilities of functional members not collocated with the

team. Military personnel were often less experienced on the teams since the military were usually on a team two to three years while civilians stayed five or more years.

The next section provides a summary of interviewee responses related to how the IPTs communicate.

### **Communication**

**How do the IPTs communicate internally within the teams and externally with other teams and customers?**

IPT members usually communicated with everyone on their teams (SPO and contractor) several times daily. Team members communicated with others on an as-needed basis. Each IPT subject primarily interacted within his own sub-IPTs, which included SPO and contractor members. Most team members indicated that they seldom interacted outside their own IPTs. This excluded people working with the IPT Analysis & Integration (A&I) teams. Most subjects were unfamiliar with the A&I teams and their missions except stating that the A&I teams were responsible for external IPT interaction. However, functional personnel also interacted with Government personnel external to both the teams and SPO. This included interaction with organizations such as Air Force Material Command (AFMC), Aeronautical Systems Center (ASC), the Office of the Secretary of Defense (OSD), and the Office of the Secretary of the Air Force - Acquisition (SAF/AQ). Also, senior management communicated more with these headquarters organizations. Full-time attached IPT functional personnel did not communicate with their reporting functional chains very

often. However, contracting and finance personnel kept their functional and team chains fully informed of their daily activities.

IPT members communicated with the user (local or HQ ACC) as requirements issues arose. The Engine IPT communicated less with the user since it had completed Critical Design Review (CDR) while the Air Vehicle IPT had only completed Preliminary Design Review (PDR). Because of this, the Air Vehicle IPT's design was less firm than the Engine IPT's. The Support System and Training IPTs had less firm designs as well.

The two main communication mediums used in the SPO were an electronic mail system called CCmail and across the aisle sub-IPT communication. Collocation enabled extensive communication with other team members. One minor IPT called the "FIRM" maintained a management information system that connected the SPO, contractors, HQ ACC, Air Logistic Centers, and Defense Plant Representative Offices (DPROs). This network provided access to CCmail and also contained computerized versions of the Statement of Work (SOW), Integrated Master Plan (IMP), Integrated Master Schedule (IMS), and Technical Performance Measures (TPMs). Workers within secured vaults did not have access to this electronic network because of their classified activities. Also, the contractors determined that it was not cost efficient to give all personnel access, especially at the subcontractor level. The telephone and voicemail system were the primary communication devices for those not on the network.

The SPO was not completely paperless but was working towards this goal. The SPO and the contractors were developing computer delivery of Contract Data Requirements List (CDRL) items. Most subjects said there was little use of paper memos within the SPO. However, at different levels within the SPO, paper letters and memorandums were still used by some subjects who thought they were the best mediums to communicate important messages. They placed information on desks since CCmail messages could often be overlooked because of their abundance. One senior manager said he had from one hundred to two hundred computer messages after being absent one week. Trip reports were also disseminated to interested personnel via CCMail.

One senior military leader stated that they needed more small meeting rooms because of the number of meetings that occurred due to forming into IPTs. Almost all the teams at all management levels held a regular team meeting once a week. The time a subject spent in meetings was directly proportionate to his level in management. Some of the smaller sub-IPTs held informal meetings early every morning in order to stay informed on the daily issues. Contracting and finance personnel stated there were far too many meetings for them to attend due to the large number of sub-IPTs they supported. Therefore, they only attended the primary IPT meetings. Major meetings called Internal Program Reviews (IPRs) for each IPT and sub-IPT occurred every six to eight weeks. The IPRs were staggered so that people attending sub-IPT meetings also could attend related major IPT IPRs several weeks

later. The SPO saved time and money by holding many meetings using video teleconferencing with the contractors.

Finally, many SPO team members wrote Weekly Activity Reports (WARs). Management collected the WARs and posted the SPO's major issues and status in one room. In this way, any member of the SPO could go to one room to find out the weekly status of activities.

The next section provides a summary of interviewee responses related to the SPO's intense up-front planning.

### **Intense Up-Front Planning**

#### **How often and what type of planning do individuals and IPT conduct?**

The primary SPO planning tools were the Integrated Master Plan (IMP) and the Integrated Master Schedule (IMS). The IMP described the program's major events while the IMS depicted when they would occur. The IMP was contractual while the IMS was not.

The IMP events were separated into a set of actions that had to be completed to close out an event. Each of these accomplishments had a set of criteria to fulfill that accomplishment. The responsible IPT or sub-IPT created a closure plan that described the required activities to satisfy that criteria. Both the contractor and SPO assigned team members responsible for signing approval for the plans. Closure plans were also created for each of the major events. The lower level closure plans descended from these higher level plans.

Most of the SPO product teams also created refined personal versions of the IMP and IMS tailored to their own products. However, these plans were still linked to the program level IMS and IMP. Each of the tailored lower level IMPs and IMSs had its own events, accomplishments, and criteria fulfilled by the activities described in its closure plan.

The IMP was structured around the hardware products the IPTs were developing. Therefore, subjects from the contracting, finance, and projects divisions did not use it since they were not directly responsible for specific hardware products. The functional workers were still tied to hardware product planning because they supported team leaders who did monitor closure plans. The functional workers planned with traditional methods such as using functional procedures and regulations to direct their planning activities.

The IMP depicts Engineering and Manufacturing Development activities and also some production tasks. An IMP for the life of the program called the Weapons System Master Plan, was being developed. It will contain activities such as site activation, maturing technology insertion, and flight test program mission rehearsal.

The projects division answered front office requests that often originated from other government agencies such as Congress, OSD, and SAF/AQ. These sporadic requests restricted the division's up-front planning so it operated in a reactive mode. However, the division was responsible for some IPD planning. One IPT called the FIRM helped the SPO plan strategically. The FIRM was tasked to support development of the Weapons System Master Plan and other production and

deployment planning. At the time of the interviews, senior management was beginning to develop production concepts that the FIRM documented for briefings. The FIRM's role was similar in Engineering and Manufacturing Development (EMD). The FIRM was tasked with gathering key SPO personnel to help structure and finalize the production plan as it progressed. Eventually, the projects division may establish a separate production planning branch.

Several subjects stated the computerized versions of the management tools, including the IMP and IMS, were too cumbersome for continual reference. For this reason, they maintained personal paper IMP and IMS copies. Most subjects considered the IMP and IMS rigid documents that did not evolve much throughout the program. Extensive IMS and IMP planning occurred before EMD. However, the subjects felt comfortable proposing any changes they thought necessary. An IMP change required a contractual change. First, the change required coordination within the related sub-IPT. Next, the change was coordinated with the Government and contractor personnel on the relevant IPT and finally approved by the Program Director via a Configuration Control Board meeting. Most subjects thought the IMP was more consequential than the IMS. Subjects were more likely to propose a schedule slip than try to close out an event before its criteria were met. An IMS change did not require a contractual change. Government and contractor focal points still had to agree to the change. The change also had to be approved by the Program Director and his counterparts. The IMS was a contract delivery item.

Most subjects said most Government team members and their contractor counterparts planned jointly. Planning was primarily characterized as a group activity since it quickly elevated to the IPT or sub-IPT level. Many subjects stated their planning was both product and process focused. The "product" part of IPD could either be a physical product or a service provided.

Program planning was mostly acquisition related. However, subjects stressed that they contacted the user if planning involved a system requirements issue. Some planning activities were uniquely user oriented, such as establishing the Combined Test Force at Edwards Air Force Base.

The next section provides a summary of interviewee responses related to team member training.

### **Training**

**How were the team members trained and how did they accomplish the cultural change to transition to IPD?**

None of the subjects received any structured training on IPD principles. They learned about IPD through work experiences and informal training sessions given by SPO leadership. Most subjects attended IPD briefings given by the first Program Director and the Technical Director during SPO calls.

The Technical Director also asked functional personnel to brief their functional areas to other team members who had no experience in those functions. One example was extensive training in cost and schedule variance control for program managers and engineers. The Technical Director wanted to provide this information to



engineers given budgets for their IPTs so they could be aware of tools that could help them. Most subjects were informed about this type of variance information. The cross-functional training occurred during IPD transition after Engineering and Manufacturing Development (EMD) contract award. It ceased after most personnel received it.

Most of the SPO participated in team building exercises that either included only Government personnel or also included contractor personnel. Several interviewees participated in team building with their sub-IPTs as well as the upper level IPTs they supported. The team building sessions were often conducted by a facilitator at the Hope Hotel on Wright-Patterson Air Force Base. Personnel went through the team building once. Some senior managers indicated they might restart it and make it a recurring activity. The participants in each of the sessions defined the goals of the team building. Goals included enhanced communication, better defined individual roles and responsibilities, and better defined strategic IPD goals. Participants thought sessions were productive even though they were at first reluctant to attend. At the time of the interviews, the SPO focal point was surveying the participants to see if teams were following any of the findings of the sessions.

Acquisition Program Development Program (APDP) training conducted by the Air Force Institute of Technology and Brooks Air Force Base was disseminated via CCmail. The projects division was responsible for processing the application paperwork. However, finance and contracting personnel applied for training through functional chains and ASC home offices. Most subjects attended APDP courses once

or twice a year. Ninety-five percent of the subjects were satisfied with the timing, frequency, and quality of their training. A few stated that more IPD training was desirable. One subject stated he had no idea what IPD was and that the IMP and the proliferation of teams confused him. Only one individual felt he was not adequately informed about all available training.

Half of the subjects attended training on the management information system and other SPO computer systems. The SPO and contractors had recently developed a newcomer orientation to explain IPD principles. The SPO realized that although IPD was familiar to its personnel, newcomers found it different from anything they had ever done. This one day course was offered to both SPO and contractor newcomers.

The next section provides a summary of interviewee responses related to the use of integrated management tools by team members.

### **Integrated Management Tools**

**What types of integrated management tools did the teams use?**

The various integrated management tools were designed to give each worker a toolbox from which he could draw. Each worker used different tools in different ways to do his particular job. The tools primarily provided information on tasks to be accomplished, task schedules, task costs, and cost and schedule variances. The SPO wanted the actual IMP accomplishments to be correlated with the cost and schedule information. One should be able to reference the IMP and IMS to find specific accomplishments not completed on schedule or within budget if cost and schedule

variances are unfavorable. Most subjects thought the tools were more process oriented than product oriented.

The primary SPO management tool was the IMP that was discussed under the planning section. Some subjects, primarily sub-IPT and IPT leaders, occasionally used the Work Breakdown Structure (WBS) together with cost and schedule variances to give them another perspective on contractor performance. The contractors had to be convinced to provide preliminary data that had not been validated because the time to validate the data kept IPTs from addressing problems in a timely manner. The Government had to learn not to overreact to data reports or not hold the contractor responsible for errors due to lack of validation.

Technical Performance Measures (TPMs) were designed to provide indicators to track how the product was developing. Lower level subjects usually did not use TPMs as much as senior management who actively looked at more than 250 of them. The TPMs were briefed to the program director weekly. Most subjects thought the primary purpose of TPMs was channelling information to higher management. The Technical Director agreed with this statement. He thought good TPMs kept him informed on program activities and saved him the time of searching out engineers for program status. He also thought standardization and documentation of TPMs was overdone. He thought people who did not think they used TPMs still used unstructured personal technical measures to track the program. The reason for the proliferation of standardized TPMs was an Air Force wide attempt to standardize acquisition methods across different programs.

Tools such as the IMP/IMS, WBS, and TPMs were usually referenced weekly. One highly effective tool used biyearly was the award fee. The first two EMD award fee determinations focused on incentives to the contractors to implement IPD. Future determinations will be focused on the product and cost, schedule, and performance accomplishments. Several subjects stated they preferred award fee contracts to any other contract types to which they had been exposed.

The Government did not use some of the contractors' more specific engineering tools, such as design aids and detailed engineering tools. The contractors also used cost and schedule critical path software which tracked items at a lower level than the SPO needed. This was level 5 of the WBS. These tools allowed the contractors to assemble costs by both function and product. Contractors tracked data company wide, combining it with data from other contracts, and also assembled it by product for the F-22 SPO.

The next section provides a summary of interviewee responses related to lessons learned for other SPOs implementing IPD.

### **Lessons Learned**

**What major hurdles did the IPD teams encounter while implementing IPD and how were they overcome? What do the teams recommend other SPOs do to transition to IPD?**

**Independent Product Teams.** The major hurdle the SPO encountered while implementing IPD was the development of "Independent Product Teams" rather than Integrated Product Teams. The four major product teams adapted more quickly than the front office anticipated when given the people, funding, authority, and capability

to develop their individual products. As a result, the IPTs tried to optimize their own specific products. Unfortunately, this meant parts of the aircraft were being developed that might not fit together as a whole unit. Instead of developing traditional "stovepipe functional" organizations, the SPO developed "stovepipe teams." The various team functions worked well together but the teams themselves never developed effective communication between each other. As a result, SPO leaders had to clarify and stress the missions of the Analysis and Integration teams. These teams had to realize they were not only responsible for integration between the team functions but also across the teams. The Program Director also instituted the Weapon System IPT to address integration at the weapon system level.

Not a Panacea. Another common lesson was IPD is not a panacea for all acquisition problems. The F-22 concept of IPD is not guaranteed to work for all programs. Also, in the future, it will be difficult to attribute the success or failure of the F-22 to just IPD as opposed to other external causes. For example, funding stability will always play a major part in program success. For a plan to be believable, the program funding profile must be solid. The F-22 had recently undergone a rephasing due to a decrease in funding that stretched out the program's length. An organization must be flexible and responsive to counter funding instability and IPTs are very flexible. Sometimes IPTs are too responsive because they can induce program oscillations via quick responses before problems are fully analyzed. Programs have to execute all disciplines from the start but must tailor their organizations to the program requirements. The F-22 had recently restructured its

own organization to more closely "mirror" the contractor organizations. In this way, SPO members could better coordinate with their contractor IPT counterparts. There is a better chance of success if Government and industry work together as a team from the beginning. Both sides must work to overcome the traditional adversarial Government-contractor relationship in order to become one team. This is easiest under a cost plus award fee contract because both sides have the same objective - - spending the Government's funds wisely. Subcontractors also become part of the team.

**Functional Stovepipes.** The most difficult culture to overcome for both contractors and the Government is functional stovepipes that are concerned about career progression. Functional organizations are positive in that they provide a clear path of progression for workers during assignments in many programs. However, functional organizations fear the IPD change because they see a threat to their career ladders. Middle management often objects because supervisors who primarily monitor other people's work are often cut out of organizations that implement IPD. Organizations cannot relieve all concerns, so they must start and absorb the chaos and mistakes as they occur.

**Buy-in.** Leadership needs to obtain buy-in to the IPD philosophy at all levels within the contractor and Government organizations. People cannot be forced to implement IPD. Formation into teams does not ensure the necessary integration and communication occurs. Integration and communication are still each individual's responsibility. Team offsites are important to achieving buy-in. One caution is that if

people work closer together, they have a tendency to listen to the Government engineers before reading the contract. This can cause constructive changes to the contract.

**Personality Conflicts.** Another lesson learned was that not every individual is comfortable with the IPD philosophy. Many introverts prefer to remain isolated within their functional divisions and not be exposed to other program areas. They feel burdened by having to communicate with people external to their own functional divisions. IPT helps keep people who try to dominate teams under control but introverts are not so easily brought out in a team. No one will accomplish his tasks if he fails to do them. Also, people must realize all disciplines on IPTs are open to compromise. It is critical to get good people on teams and to find leaders who can pull out introverts and control overbearing members. A SPO must be willing to replace people who do not fit into IPTs.

**Bureaucratic Resistance.** Another lesson is SPOs should not underestimate bureaucratic resistance from functional organizations and personnel systems while implementing IPD. Higher ranking civilians need a certain number of subordinates to justify their pay grade. The expertise of these higher ranking civilians is critical to the success of the IPTs. However, under IPD these civilians may only have teammates and no subordinates. Military personnel are also evaluated on how many people they supervise. Also, administrative support in the Government is sometimes based on how many people of certain grades are working in an organization and not on how many teams need secretaries. Industry also has the same problem with

functional organizations who see their power pyramids eroding and manufacturing personnel who do not want to change. SPOs should not assume they are the only ones experiencing problems implementing IPD. IPD may be more of a cultural change for industry than for the Government.

**Early Development.** Finally, IPD should be implemented from the very beginning of a program. Planning should be extensive and should be focused on the product from the onset. It is important to design the structure of the program early and to incorporate a suitable contract type with requirements for the tools essential to the IPTs. Only then should teams be organized. Team organization is an extensive and difficult activity, especially choosing suitable leaders and grouping together necessary functions for each team. The F-22 extensively planned and laid the groundwork at the beginning of the program long before it began implementing IPTs after EMD contract award.

### **Summary**

This chapter provided a summary of the results of the interview questions. It was organized by separating the results into six sections representing the investigative questions of the thesis. Chapter Five will present a conclusion for the F-22 Integrated Product Development case study and will present recommendations for future studies.



## **V. Conclusions and Recommendations**

### **Introduction**

This chapter reviews the first four chapters of the thesis. The chapter also discusses the limitations of the study, and in particular, the interview process. It summarizes the more significant findings and results of the interviews. Finally, the chapter presents recommendations for future studies and presents a conclusion for the F-22 Integrated Product Development case study.

### **Review**

This thesis was made up of five chapters. Chapter I was an introduction that described the research question and set the scope of the case study. Chapter II was a literature review that summarized the development of CE and IPD in industry and the Air Force. It also described the characteristics and elements of IPD. Finally, it gave a description of the F-22 program. Chapter III described the research methodology. It described how the teams and personnel were evaluated for possible selection for interviews and detailed how the actual interviewees were chosen. It also described the format and method for the interviews. Finally, it described how the data was analyzed. Chapter IV summarized the results and findings of the interviews. This chapter contains conclusions and recommendations for future research.

### **Limitations**

This study was limited by the time the researchers could devote to the thesis and to the availability of subjects to be interviewed. Because of time constraints, the

researchers chose to only interview personnel residing in the F-22 SPO on Wright-Patterson Air Force Base. Contractor and subcontractor personnel were predominant members of the IPTs and outnumbered the Government personnel. An extensive study would have interviewed contractor personnel as well as SPO personnel. However, there were too many contractors at too many different locations to allow any type of sampling from their personnel. There were other Government team members aside from those working in the SPO. The Air Logistic Centers (ALCs) and Air Combat Command (ACC) both had representatives who interacted with the IPTs. Also, Defense Plant Representative Office (DPRO) personnel were important team members. They were not interviewed for the same reason the contractors were not interviewed.

Two important subsets of the SPO were not interviewed. There were three user representatives permanently located in the SPO. The researchers scheduled appointments with these representatives but each time the interviews had to be cancelled because an important SPO meeting precluded an interview. The other subset not interviewed was the Training IPT. The Training IPT lagged behind the other three IPTs due to its dependence on the development of the other IPTs' products. For this reason, the researchers concentrated on the other three IPTs due to lack of time to interview personnel from all four of the IPTs.

Another limitation of this study is its applicability to other programs. Readers need to compare the characteristics of the F-22 program with those of their own programs in order to determine the relevance of the study.

## **Conclusions**

The next section reviews some of the more important views that the F-22 subjects related during the interviews.

**Organizational Structure.** The user should have local representatives on the IPTs who are active team members and provide inputs for requirement issues. Support personnel, such as contracting and finance, should be physically separated from the IPTs for three reasons. First, there is usually not enough manpower to allow dedication of a functional representative to each IPT sub-team. Second, most of the functional members have activities that effect the entire weapon system and span across all IPTs, so they may need to communicate with other functional workers to obtain a program-wide perspective. Third, they use common reference materials that may not be feasible to place in each IPT's area. However, functional personnel should realize that being separated from the IPTs may cause them to miss notification of important issues. It is probably advantageous for functional civilians to report via their functional chains as opposed to team-oriented chains. IPT team leaders may not observe many of the functional activities and may have a difficult time obtaining high ratings for their personnel. However, team leaders should provide inputs to functional personnel performance evaluations.

**Communication.** Two valuable communication mediums are electronic mail and across the aisle sub-IPT communication. The most important advantage of collocation is enhanced communication with team members. Meetings are prevalent in IPTs and the time spent in meetings is directly proportionate to the management

level. Contracting and finance personnel will not be able to attend many meetings due to the large number of sub-IPTs they support. Weekly Activity Reports (WARs) and trip reports are also good ways to inform team members.

**Intense Up-Front Planning.** IPD should be implemented from the very beginning of a program. Planning should be extensive and should be focused on the product from the onset. It is important to design the structure of the program early and to incorporate a suitable contract type with requirements for the tools essential to the IPTs. Only then should teams be organized. It is very important for the Government and contractors to plan using tools such as the Integrated Master Plan (IMP) and the Integrated Master Schedule (IMS). The IMP describes the program's major events while the IMS depicts when they occur. Both the contractor and Government should have assigned team members responsible for signing approval for closure plans for each criterion of the IMP. Government team members and their contractor counterparts should plan jointly.

**Training.** SPO members may have to learn about IPD through work experiences and informal training sessions. One way to train workers is to have functional personnel brief their functional areas to other team members without experience in those functions. Team building exercises that either include Government personnel and contractor personnel are another way to help transition to IPD. If a SPO can establish a newcomer's briefing it would help train new personnel.

**Integrated Management Tools.** The various integrated management tools give each worker a toolbox from which he can draw different tools to do his particular job. The tools primarily provide information on tasks to be accomplished, task schedules, task costs, and cost and schedule variances. IMP accomplishments and the WBS should be correlated with the cost and schedule variances. Technical Performance Measures (TPMs) provide indicators to track how the product develops. Lower level subjects will not use TPMs as much as senior management.

**Lessons Learned.** One major hurdle to implementing IPD is the development of "Independent Product Teams" rather than Integrated Product Teams. When IPTs receive the people, funding, and authority to develop individual products they can over optimize them. Analysis and Integration (A&I) teams are critical because they help ensure the product teams interact. A Weapons Systems IPT also can help ensure cross-team integration between the IPTs. SPOs should understand IPD is not a panacea for all acquisition problems. The F-22 concept of IPD is not guaranteed to work for all programs, and other programs should tailor IPTs to fit their needs. Also, influences, such as budgetary funding support, play major roles because planning requires a stable funding profile. Both sides must work to overcome the traditional adversarial Government-contractor relationship and become one team. This is easiest under a cost plus award fee contract because both sides have the same objective. The most difficult aspect to overcome for both contractors and the Government is functional organizations that are concerned about career progression. Formation into teams does not ensure the necessary integration and communication

occurs. Integration and communication are still individual responsibilities. Another lesson learned is not every individual is comfortable with the IPD philosophy. Many introverts prefer to remain isolated within their functional divisions. The next section contains the conclusion to the F-22 IPD case study.

### **Recommendations for Future Research**

The researchers identified several areas for potential research. 1) This study was limited to interviewing members from the SPO. One potential research area is interviewing contractor IPT personnel instead of SPO personnel. 2) Another area is a joint study of the SPO and contractor team members of one IPT. This study would offer a more detailed study of one team and how its various members interacted with each other. In this way, the study would build upon the broader knowledge obtained in the SPO-wide case study. 3) Researchers could also interview user IPT personnel at both the Air Logistics Centers and at Air Combat Command Headquarters. This research would provide important information on how the user interacted with the SPO and on how well the user was satisfied with IPD. 4) Finally, researchers could study other programs who are in the initial stages of IPD implementation to examine how they form into IPTs.

### **Summary**

The overall investigative purpose of this case study was to answer the question "How are the F-22 System Program Office's (SPO) Integrated Product Teams currently implementing Integrated Product Development?" This thesis examined the

six areas of organizational structure, communication, intense up-front planning, training, use of integrated management tools, and lessons learned in order to answer this question. The SPO emphasized planning up-front to establish an organizational and contractual structure that empowered workers at the lower levels to develop their products. Constant communication with all other functions of the IPT and other IPTs was stressed. Training was primarily done to transition to IPD but was beginning to be reemphasized. Each team member tailored his own management toolbox to the activities necessary to perform his duties. The most important lesson learned was to avoid letting Integrated Product Teams evolve into Independent Product Teams.

## **Appendix A: Interview Questionnaire**

### **Background**

1. When did you join the F-22 SPO? (date and stage of program)
2. What is your job title? Where on the organizational chart are you located. What other job titles in the F-22 have you held?
3. What are your present responsibilities? What other responsibilities have you held?
4. What IPD teams are you currently on? What other teams have you been on?
5. What are the missions of your IPT(s)?

### **SPO/Team Organizational Structure**

**What is the organizational breakdown of the IPTs?**

1. What job disciplines make up the IPTs you work on?
2. How many members of your team continually support more than one IPD team?
3. Are contractor and user representatives resident in the F-22 SPO?
4. Is your office located with the offices of other team members? If not, where is it located and what are the advantages and disadvantages of this arrangement?
5. What is your official chain of command and who has input into your performance evaluation?
6. What is your team reporting chain?
7. Who do you interact with to solve problems and issues?
8. Does the organizational structure provide you with adequate visibility and input into all the activities you feel are necessary to do your job?
9. Do you think your team has the appropriate mix of experience and skill levels to meet team requirements?
10. What is the turnover rate on each team?



11. Regarding team organizational structure, is there anything you can add to what you have already shared?

### **Communication**

**How do the teams communicate internally within the teams and externally with other teams and customers?**

1. How often do you talk with people you work with? (for example: contractors, users, headquarters, other teams, other team members, and your reporting chain of command)
2. Is the above communication regular or intermittent? Is it one-on-one or group oriented?
3. Do you hold team meetings? How often? At which team levels?
4. How is communication accomplished? (computer LAN's, memos, phone, across aisle, etc.)
5. How are your duties effected by being accountable to more than one individual? (i.e. due to being on more than one team or being functionally matrixed.)
6. Regarding communication, is there anything you can add to what you have already shared?

### **Use of Intense Up-front Planning**

**How is up-front planning accomplished in the SPO?**

1. Describe the planning process for major milestones and other important activities.
2. How is this planning documented and revised?
3. How much of the planning process is individual versus group effort?
4. How are the user, contractor, and other team members involved in the above planning?
5. How and when do you provide input to the IMS and IMP?
6. Is your planning product focused? If so, how?

7. Regarding planning, is there anything you can add to what you have already shared?

## **Training**

**How are team members trained?**

1. What training have you received? (behavioral, conflict resolution, computer, technical, IPD, etc.)
2. Who developed and conducted the training and where was it performed? (conducted by the SPO, AFIT, contractor, functionals, etc.)
3. What was the timing and frequency of your training?
4. Are the timing, frequency, and quality of the training adequate for your job requirements?
5. Are you adequately informed about the availability of training and able to attend when you need to?
6. Regarding training, is there anything you can add to what you have already shared?

## **Use of Integrated Management Tools**

1. What management techniques and tools do you use to help integrate team activities and how do you use them? (examples: IMS, IMP, Technical Performance Measures, WBS)
2. How often do you use each tool?
3. Which tools are computerized?
4. What information does each tool provide to conduct your job and are you adequately prepared to do your job based upon this data?
5. If the contractor uses any other tools, do you use them and how helpful are they?
6. What are the advantages/disadvantages of each of the tools?
7. Are the tools product oriented?

8. Regarding tools, is there anything you can add to what you have already shared?

**Lessons Learned**

1. What major hurdles did the IPD teams encounter while implementing IPD and how did they overcome them?
2. Do you have any lessons learned which can help other SPOs attempting to implement IPD?

## **Glossary of Acronyms**

**ACC: Air Combat Command**

**AFB: Air Force Base**

**AFTT: Air Force Institute of Technology**

**AFMC: Air Force Materiel Command**

**AFSC: Air Force Systems Command**

**A&I: Analysis and Integration**

**ALC: Air Logistics Center**

**APDP: Acquisition Professional Development Program**

**ASC: Aeronautical Systems Center**

**ASD: Aeronautical Systems Division**

**ATF: Advanced Tactical Fighter**

**CAD: Computer Aided Design**

**CDR: Critical Design Review**

**CDRL: Contract Data Requirements List**

**CE: Concurrent Engineering**

**CPT: Critical Process Team**

**DoD: Department of Defense**

**DPRO: Defense Plant Representative Office**

**EMAIL: Electronic Mail**

**EMD: Engineering and Manufacturing Development**

**FAR: Federal Acquisition Regulations**

**IDA: Institute for Defense Analyses**

**IMP: Integrated Master Plan**

**IMS: Integrated Master Schedule**

**IPD: Integrated Product Development**

**IPDT: Integrated Product Development Teams**

**IPR: Integrated Program Review**

**IPT: Integrated Product Team**

**IWSM: Integrated Weapon System Management**

**MIT: Massachusetts Institute of Technology**

**OMB: Office of Management and Budget**

**OPR: Officer Performance Report**

**OSD: Office of the Secretary of Defense**

**PDR: Preliminary Design Review**

**SAF/AQ: Office of the Secretary of the Air Force - Acquisition**

**SOW: Statement of Work**

**SPO: System Program Office**

**TPM: Technical Performance Measure**

**USAF: United States Air Force**

**WAR: Weekly Activity Report**

**WBS: Work Breakdown Structure**

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a. Highly  
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b. Significant

c. Slightly  
Significant

d. Of No  
Significance

5. Comments

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